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High resolution soil records of impact-ignited fires at 4 kyr BP in various regions of the Near East, West Europe and Peru.

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The critical debate on the ignition-efficiency of extraterrestrial impacts has emphasized the importance of identifying the fired record that was formed at the exact time of the impact. This is aimed to avoid confusion with lightning-ignited wildfires that could have started later due to impact-related atmospheric changes or vegetation destruction. Here we report on diverse fired situations related to the 4 kyr BP impact that were encountered in cumulative soils developed on flood plains and low-lying depressions from various regions: the Moche valley (Peru), the Middle Euphrates plain (Syria), the Khabur basin (Syria), Ebeon and Les Loups (West France), Baho, La Capoulière and Mas de Vignole (South France). The study focusses on well-preserved fired stratum that benefited from rapid burial just following the 4 kyr BP impact. The distinctive fired stratum in the field display similar patchy burnt traces that locally appear as a stratigraphical discontinuity marked by a burnt soil surface, or an abrupt change of soil morphology. The attribution of the fired stratum to the 4 kyr BP event has been

established from absolute radiometric dating and archaeological data. A detailed study of the fired stratum using a standardised sampling method and a multi-analytical protocol has lead to identifying a similar assemblage of exotic debris at the different sites which shows distinctive characteristics of impact by-products [1]. Examination under the petrographical microscope and the environmental SEM of the exotic components within their host organo-mineral soil matrix has provided diagnostic criteria relevant to discriminate the *in situ* fired signals linked to the 4 kyr BP impact (FS_{in}) from the effects of subsequent reworking (FS_{rw}).

Three types of *in situ* fired-signals have so far been identified. $\mathrm{FS}_{in}1$ corresponds to a burnt soil surface with a three-fold fabric formed by the carbonised vegetation, fired-cracked darkened soil aggregates and the underlying charred rootlets. The evidence for ignition by the fallout of the impact ejecta is represented by (i) local firing of the host soil matrix at the contact with the exotic flow glass; (ii) replacement of the root and plant tissues by an exotic carbonaceous phase formed of micro-spherules and fibres. This carbonaceous phase derives from originally fresh organic matter. $\mathrm{FS}_{in}2$ is characterized by the patchy association of the $\mathrm{FS}_{in}1$ burnt surface with clusters of fist-sized budding vesicular slags. The slags consist of impact flow-glass that is finely imbricated with locally-heated host soil materials. The vesicles of the glassy slags and the fine pores of the embedding soil are coated by films of splashed-droplets that derive from exotic carbonaceous phases. $\mathrm{FS}_{in}3$ displays the original soil surface that is coated by a carbonaceous film formed from the spray of a kerogen emulsion. The concentration of coarse exotic debris embedded within moderately-heated host materials occurs locally. The three FS_{in}facies are explained to result from the pulverization at the soil surface of a hot impact ejecta consisting of solid debris and volatile-rich fluid condensates. The spatial variability of the ignition processes reflects the compositional heterogeneity of the volatile and hot fluid components of the impact ejecta, particularly with respect to the distinctive carbonaceous phases.

A reddish fired stratum (FS_{rw}I), formed of air-transported soil aggregates that were eroded from the fired soil surface just following the ejecta fallout, is commonly overlying the FS_{in} facies. This close succession attests to the occurrence of violent hot air turbulence that would possibly express effects of the thermal heat pulse known to result from ballistic re-entry of ejecta. The high wind intensity is attested by surface abrasion of the reworked impact-debris, their fragmentation, and loss of the finer components compared to a relative increase of the coarser ones. This contrasts with the random reworked fired-signal (FS_{rw}II) that contains occasional exotic debris and carbon-vaporised charred plants. Characteristics relevant to the impact-linked firing can still be recognised, although partly altered by post-depositional processes. The sedimentary reworking has erased the original linkages of the impact-related debris

with the host materials. The spatial survey of the fired stratum attests that the patchy pattern of FS_{in} is not the result of preservation conditions of the *in situ* burnt surface, but would more likely express the reality of the discontinuous original firing. The distal dispersion of the 4 kyr BP impact ejecta is thus concluded to have generated erratic ignition due the local fallout of hot debris, but not giant wildfires.

[1]. **Compositional evidence for multiple source areas of the 4 kyr BP distal impact-ejecta.** M.-A. Courty et al.. Symposium PS12, this issue.